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A SUMMARY OF THE U.S. NAVY PROGRAM AND FY 1967 PROGRESS IN WEATHER MODIFICATION AND CONTROL

Navy Weather Research Facility
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A Summary of

THE U.S. NAVY PROGRAM AND FY 1967 PROGRESS IN WEATHER MODIFICATION AND CONTROL

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Skyland Lodge, Skyland Drive, Virginia

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Purpose and Scope

CAPT W. L. SOMERVELL, Jr., USN, Navy Subchairman

The Navy's overall objectives in weather modification have changed but little during the last several years. During the past year, however, our expectations of what, when and how these objectives can be achieved have crystalized considerably. It appears that the basic research and exploratory development have progressed to the point where it is now possible to commence advanced development for achieving certain specific goals. Thus, increasing effort is being devoted to engineering specific cloud modifications through computer modelling, and to developing materials, equipment and techniques for treating clouds.

The ability to perform even relatively simple cloud modifications could substantially enhance the effectiveness of many naval operations. These, then, will be attacked first in order of present feasibility. It is anticipated that from this will come the capability to perform more complex modifications, and that within the foreseeable future we will be able to attack the problems of storm and climate modification with some confidence. The Navy has and will continue to cooperate with others in the development of this field, and participation with ESSA in Project STORMFURY will continue, in the belief that one of the best ways to eventually master hurricane and typhoon modification is to get in and work on it.

Research in Support of the NWC Weather Modification Program

CDR Max C. JACK, USN

and

Dr. W. G. Finnegan

Naval Weapons Center, China Lake, California

The Naval Weapons Center, China Lake, has discontinued research in weather modification, and is currently devoting their efforts to the field of environmental application research.

We are however, continuing work in nucleation. Dr. Odencrantz is keeping his ice box busy with nuclei counting and particle charge work. We expect to remain active in this area.

In addition we are supporting nucleation research at Colorado State University and South Dakota School of Mines.

We are also continuing cumulus work with three contractors, with hope of getting some quantitative answers in addition to cloud physics research.

Warm fog and warm stratus continue at the top of our priority. We have a warm fog and stratus experiment at Hollister. At present there is nothing to report since the weather has not cooperated.

Dr. Finnegan will now give you some interesting observations on ice crystals and particle charge.

Continued evaluation of pyrotechnic combustion as a process for generating silver iodide based freezing nuclei has given new information on potential nucleation efficiencies and on mechanisms of nucleation. Information on aerial clustering of ice crystals and on a possible mechanism for ice crystal growth has also been gained. The presence of electrical charges on freezing nuclei,

ice crystals and supercooled cloud droplets has been shown to be an important factor with influence on the rates, mechanisms, extent and direction of atmospheric processes. Atmospheric contamination, by a wide variety of chemical compounds in gaseous form, has been shown to markedly affect the nucleation of freezing of supercooled cloud droplets and the resulting electrical charges on ice crystals.

A comparison of silver iodide freezing nuclei activity spectra, determined by different techniques at different facilities for the same pyrotechnic composition, strongly suggests that the presence or absence of electric charge on the nuclei has a marked effect on the nucleation efficiency and on the mechanism of nucleation. Nuclei which are too small to function by a sublimation mechanism at temperatures above -10°C show high activity between -5° and -10°C when charged positively and apparently function by a contact nucleation process. This charge phenomena together with the hygroscopic character of mixed silver iodide-alkali iodide nuclei must be considered in the design of atmospheric experiments; the functioning of freezing nuclei will be affected by the mode of placement of these nuclei into cumulus clouds, below cloud base or from the ground.

Aerial clustering of ice crystals into snowflakes has been observed at Yellowstone National Park following pyrotechnic seedings with silver iodide containing nuclei. Evidence suggests that aerial clustering of ice crystals may also occur in nature. Since this phenomenon could have an important bearing on the rates of precipitation processes, a study has been started in the NWC cloud chamber to gain information. Aerial clustering of ice

crystals has been shown to occur in the cloud chamber but the exact details of the process are not completely understood as yet; overseeding is an important factor.

Careful replications of ice crystals using the methyl 2-cyano acrylate vapor process and a study of the replicas with a "Stereo-Scan" electron microscope has given new evidence for a growth mechanism for ice crystals. Microscopic observation of small ice "whiskers", predominantly at crystal boundaries, suggests that crystal growth involves condensation of water vapor from the surrounding air onto the growing ends of the whiskers and subsequent transport to the crystal base. A diffusional and heat transfer limited model of the growth process is being studied.

Progress in Engineering Weather Modification Experiments by Computer Modelling

Clement J. Todd

Navy Weather Research Facility

Weather modification research at NAVWEARSCHFAC during the past year has continued to emphasize systematic development of mathematical models of cloud processes, as outlined in our presentation at the 8th Interagency Conference, and the use of these models to investigate the feasibility of and optimum treatment for various modifications. Primary effort has been devoted to the following:

Warm Fog

Very little new computing has been done on the warm-fog clearing problem, but considerable effort has been devoted to studies on the best means for implementing those treatments that the models predict will be most effective. The spraying of concentrated solutions

does not seem to be a good approach; because spray systems that can produce droplets of the proper size are not designed for large capacities, nor do they permit careful control of the droplet size distribution. Hygroscopic powders, on the other hand, can be preground, sorted in centrifugal blower separators and packaged into the desired 5 to 10 micron range, with virtually no small particles. Two major fertilizer companies have expressed a desire to participate in this research, and one has prepared samples which appear satisfactory in preliminary laboratory tests. The Navy has a helicopter-borne dry-insecticide dispenser, designed for mosquito suppression, that appears suitable for preliminary field tests with these powders. It is anticipated that dusting treatments may be incorporated in warm-fog dissipation experiments this winter.

Condensation-Coalescence Precipitation

A mathematical model has been programmed, and exploration using it has begun. Initial exploration indicates that there is a great potential for modifying warm-cloud precipitation with hygroscopic nuclei treatments.

Ice-Phase Precipitation

A mathematical model has been programmed to compute ice-crystal growth and fall speed. This program is being used to explore the concentration of ice nuclei as a function of temperature and time required to clear supercooled fog.

Engineering design of compressed-air nozzles for nucleating supercooled fog is being carried out in conjunction with an experimental program conducted by the Army at CRREL.

Climatologies of the Potential Ice-Phase Modification of Convective Clouds

A mathematical model for analyzing radiosonde data to determine the potential for ice-phase modification of convective clouds has been programmed and run extensively on historical weather records. An example is presented in a climatology for the Caribbean, which shows that cumulus seeding should be effective only infrequently during winter and spring but quite effective in the summer and autumn.

Operational By-Products

As a by-product of convection-analysis models, an operational computer program has been developed for analyzing the vertical structure of the atmosphere from available sounding data. It is anticipated that these analyses will be used for day-to-day assessments of weather-modification feasibility, when convective cloud modification is performed operationally. During the interim, computer-produced vertical cross sections (both space and time) of the thermodynamic parameters used in meteorology are being used by Naval Weather Service units to facilitate operational analysis.

Project STORMFURY Operations-1967

Mr. Max W. Edelstein

Naval Weather Service Command

Since the inception of this joint Department of Defense-Department of Commerce hurricane modification program, experiments have been performed on just two storms, Hurricane Esther in 1961 and Hurricane Beulah in 1963. Opportunities for seeding were somewhat limited by restriction to a prescribed area, a band in the

southwestern North Atlantic between Bermuda and Puerto Rico.

Acting upon a recommendation from the STORMFURY Advisory Panel, approval was obtained to have rules for storm seeding eligibility changed. For the 1967 season any suitable storm in the southwestern North Atlantic was eligible for seeding as long as there was a small probability (10% or less) of its center approaching within 50 miles of a populated area within 24 hours. This change in criteria was made possible by the increased accuracy of hurricane forecasts.

Early in August a comprehensive "dry run" was held in the Jacksonville, Florida area. Participating units provided aircraft from the Air Force 53rd Weather Recon Squadron, the Environmental Science Services Administration Research Flight Facility, and the Navy Weather Recon Squadron Four and Attack Squadron Thirty-five. In addition, representatives from the Federal Aviation Administration were present to assist in airspace reservation planning. A simulated "eyewall" experiment was conducted the first day, and a "rainband" experiment the second day. A description of these experiments is contained in the 1966 STORMFURY Annual Report.

For the first time in 14 years, or ever since official United States Weather Bureau forecasts were recorded by latitude and longitude for the areas and times concerned, no eligible hurricane appeared during the operational period 8 August to 15 October. However, the completion of a comprehensive Operations Plan, and the valuable training acquired during the "dry run", will help in future hurricane modification experiments.

Flight Studies of Glaciation in Clouds at -4° To -6°C

R. E. Ruskin

Naval Research Laboratory

At the 1966 meeting, Dr. Dinger presented a survey of several types of the atmospheric studies at NRL. This year we will cover mainly the cloud physics flight program, omitting the continuing studies of cloud condensation nuclei, atmospheric electrical effects, stratospheric water vapor measurements, and instrument development.

Most of the NRL cloud physics flight experiments in recent years have been conducted cooperatively with aircraft and scientists of other activities, in order to provide multiple aircraft traverses at several altitudes in the clouds. Results of these experiments, as in the case of Project Whitetop, raise a question as to whether, for many maritime cumuli, precipitation may be reduced if the usual hypothesis for the seeding mechanism is true; i.e., that precipitation is enhanced by ice crystals on artifically added freezing nuclei growing rapidly at the expense of the liquid water of the cloud. We found that frequently too many natural ice particles for optimum precipitation growth were already present at temperatures as warm as -2° to -6°C.

During 1967 the NRL cloud physics group published jointly with ESSA in the Journal of Applied Meteorology some of the results of the measurements made in the 1965 STORMFURY project. In these experiments cumulus clouds were seeded with silver iodide pyrotechnic "Alectos" developed at China Lake. In addition to various cloud measurements by aircraft of ESSA, USAF, and the U. S. Navy Weather Reconnaissance Squadron 4, NRL made measurements with the

cooperation of the Navy Weather Research Facility, Norfolk, to determine the changes in cloud ice. The results indicated that natural glaciation was unexpectedly prevalent at temperatures only 2 to 5° below 0°C. The more active updraft regions were more ice free, hence more responsive to seeding. The seeding apparently produced considerable increase in buoyancy in several clouds, as manifested by increased growth of the cloud top.

In October 1966, a series of joint flights with no seeding was made with Dr. Mossop and other scientists of the CSIRO in Australia with their well-instrumented cloud physics aircraft. Each aircraft was equipped with two types of Formvar cloud particle replicators, all designed differently. Both planes had an assortment of other cloud physics instruments. One valuable instrument on the CSIRO plane was a "cloud box" cloud chamber for determining in flight the number of freezing nuclei active at various temperatures.

Combining the measurements of the two sets of instruments provided cross checks of the reliability of observations that ice crystals, as well as pellets, were present in clouds with tops as warm as -4.5°C in such large numbers as to indicate that only about a hundredth of 1% of the crystals resulted from growth on sublimation nuclei. It was concluded that some 10,000 to 1 ice-multiplication process must have operated nearly independently of the nuclei present. As in the 1965 Caribbean observations, the data indicated that the glaciation was more prevalent in the older, less active regions of the cloud and remained "patchy" even after a considerable time had passed. From the Bergeron-Findieson mechanism of liquid droplets evaporating and recondensing on ice

particles, it was surprising that much of the water only a few meters from the ice "pockets" remained liquid for a half hour or longer in some clouds. Apparently mixing is not appreciable in all sizes of eddies. In clouds which are as much glaciated as we found, it seems that the only cloud volume which would be greatly influenced by seeding is the active updraft region, where natural ice appeared to form only at higher altitudes. While it now appears doubtful that precipitation would be increased by the direct effect of seeding in these clouds, the indirect effect of increased buoyancy by seeding in the updraft portions would sometimes increase the cloud growth enough to augment entrainment of more moisture at the base and improve the overall dynamics of the system toward precipitation. The same conclusions seem to follow from partial analysis of data from this summer's joint flight study of cumuli with ESSA and MRI over the Caribbean. No seeding was included in this project. In addition to the ice information collected, an unexpected finding in those clouds was the frequent occurrence of large unsaturated cloud regions when clouds were growing into a dry atmosphere above the tradewind inversion. In some cases the total water content measurement by our cloud evaporator-Lyman-alpha instrument indicated that even with all water and ice evaporated, the air in the cloud was not saturated.

Data are still being analyzed toward understanding more about when and where the warm glaciation can be expected. Contrary to previous indications, ice crystals apparently do not always correlate with large drops or ice pellets in the cloud. While a start has been made toward understanding why some seeding experi-

ments may be successful using freezing nuclei while others may produce negative results, much more must be known before a reasonable predictability of seeding results can be expected. So far we have not obtained these types of data in continental type clouds which generally have 10 to 100 times more and smaller droplets compared to maritime ones of similar water content.

Office of Naval Research Program in Weather Modification

Mr. James P. Hughes

Office of Naval Research

The Office of Naval Research continued sponsorship of cloud physics investigations by colleges, universities and private enterprise. For the most part the ONR sponsored investigations were discussed in detail at the last meeting of this group, and there has been little significant progress to report at this time. Therefore, a brief description of each contract should suffice.

Dr. Woodcock is continuing his investigations of trade-wind cumulus at the University of Hawaii. The objective of this effort is to artificially induce sufficient convection in the lower atmosphere of the trade winds to grow a cumulus cloud by seeding with sodium chloride or sea salt.

Dr. Dobbins of Brown University is studying the growth rates of atmospheric aerosols at various size ranges up to large drop sizes. Both optical and acoustical measuring techniques are being used.

Investigations by Dr. Hoffer at the University of Nevada on the nucleation and freezing processes of raindrops and those at Cornell Aeronautical Laboratory by Dr. Livingston on the micro-

structure of ice were continued during the Fiscal Year 1967.

Dr. Neyman at the University of California continued his re-analysis of the Swiss hail-suppression experiments, and data of other large randomized experiments, to determine whether or not there is a real effect in present attempts to modify weather. To date, thirteen of the selected nineteen randomized experiments have been analyzed. These analyses show an increase in precipitation in some experiments and a decrease in others, and sometimes increases and decreases within the same experiment.